POSSIBILITIES AND UTILIZATION OF SOFTWARE SYSTEM FOR COAL SEAM ECONOMICAL THICKNESS DELIMITATION

MOŽNOSTI A VYUŽITÍ PROGRAMOVÉHO SYSTÉMU PRO VYMEZOVÁNÍ BILANCOVANÝCH POLOH V UHELNÝCH SLOJÍCH

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Abstract

The article deals with possibilities of utilization of the designed and developed BilPol software system that extremely facilitates, accelerates and specifies the very important initial stage of estimation of coal reserves. The system quickly and transparently compiles and illustrates logs of boreholes and cuttings with indicated seams and benches. In the user-friendly and intuitive graphic environment it provides the user tools for automated search and definition of economical seam parts. In the logs there are indicated in addition segments fulfilling some important criteria - e.g. maximum average content of ash as a qualitative parameter of usability conditions. The user application processes data of a coal database containing specifications of layers in boreholes and represents it graphically in a transparent form. The database has been conceived to be generally applicable on all coal deposits in CR. Using the BilPol system it is possible to compile more quickly and more precisely variant 3D models of balance and sub-economical parts of seams for subsequent calculation of coal resources. The system is implemented using the Microsoft Visual Basic language. While creating the program the additional component Microsoft Common Dialog Control 6.0 has been used for creation of the user environment [4]. Access to the database in the MDB format is provided through the Microsoft DAO 3.6 Object Library.

Abstrakt

Článek pojednává o možnostech použití navrhnutého a vyvinutého programového systému BilPol, který v maximální míře usnadní, urychlí a zpřesní velmi důležitou úvodní fázi výpočtu zásob uhlí. Systém rychle a přehledně sestavuje a znázorňuje profily vrtů a záseků s vyznačenými slojemi a lávkami. V uživatelsky přívětivém a intuitivním grafickém prostředí nabízí uživateli prostředky pro automatizované vyhledávání a definici bilancovaných poloh. V profilech jsou dále vyznačeny úseky splňující některá důležitá kritéria - např. maximální průměrný obsah popela jako kvalitativní parametr podmínek využitelnosti. Uživatelská aplikace zpracovává data uhelné databáze obsahující specifikace poloh ve vrtech a v přehledné formě je graficky reprezentuje. Tato databáze byla koncipována tak, aby byla univerzálně použitelná na všech uhelných ložiscích ČR. S využitím systému BilPol je možno rychleji a přesněji sestavovat variantní prostorové modely bilančních a nebilančních částí slojí pro následný výpočet zásob uhlí. Systém je implementován za použití jazyka Microsoft Visual Basic. Při tvorbě programu bylo využito k vytvoření uživatelského prostředí přídavné komponenty Microsoft Common Dialog Control 6.0 [4]. Přístup k databázi formátu MDB je prováděn pomocí objektové knihovny Microsoft DAO 3.6 Object Library.

Key words: programming system, seam, borehole, coal, economical thickness, identification.

1 INTRODUCTION

Determination of economical (balance, sub-economical, under-limit) thickness in profile of coal seam is a presumption for finding out estimation of coal quantity on deposit within calculation of resources of the raw material. Therefore the BilPol software system has been designed and implemented which allowing easy and quick determining economical thicknesses of seam and its benches according to various limit values of principle parameters of usability conditions. The system allows mass data processing, its visualization and option of interactive access in the following steps:

- Derivation of approximate value of ash content A^d in layer based on petrographic description,
- Graphic depiction of analytically specified and derived values A^d,

- Determination of geological and economical thicknesses of seams and calculations of corresponding weighted means of diameters of chosen deposit parameters in such thicknesses,
- Determination of genetic coal benches and partings, i.e. coal benches separated by partings being correlatable on a large interval of seam occurrence. Automated determination of economical thicknesses of such benches according to entered criteria and automated determination of corresponding weighted means of selected deposit parameters in the thicknesses.

A manual processing data from a deposit database is considerably non-operative and slow. The proposed software system brings a significant facilitation, particularization and especially acceleration of the entire process. From the point of view of creation of coal deposit models they may be divided to the following ones:

- Geological model of seams
- Variant model of economical seams
- Geological model of benches
- Variant model of economical benches

The BilPol application allows to determine automatically in profiles of coal seams affected by individual boreholes the economical seam parts according to the default limit values of ash content A^d = 50, 40, 35 and 30 %, and at the same time it gives an option to select any other limit values.

There may occur in the modelled seams genetic benches, i.e. coal beds separated by partings that may be rated independently as well according to changing limit values of ash content. In each profile of the seam affected by surface or mine borehole there is necessary to specify first boundaries (depths in borehole log) of individual coal beds and partings. Consequently the economical segments are determined in the individual coal benches. From the data a spatial shape of the coal benches and partings may be determined according to different limit values of ash content.

The application allows processing data from a deposit database [3] of lignite deposits, subbituminous coal deposits and deposits of bituminous coal. Essential demands made on the system involve a user-friendly interface and transparency. The system presents data in a well-arranged graphic form with an option of interactive control. During time-consuming activities such as calculations, data mining from the database or initialization of graphic elements the user is informed on the events via information messages notifying of the actual status of the system. The user of the system is notified by displaying warning messages of more important operations such as overwriting of file on disk, repeating of calculation, overwriting of values while selecting an interval, attempts to store values without completing mandatory items and other with an option to go back. In the graphic window of the analysed and derived values an information about a borehole or cutting, seams, layers and a more detailed description of a legend is then displayed in the message line.

The use case diagram is one of specifications of the versatile UML graphic language for visual system modelling (see Fig. 1). The use case diagram is used for modelling activities that may be performed by participants using the system, defines meaningful relations between participants and use cases and finally defines roles assigned to persons or objects using the given system [1].

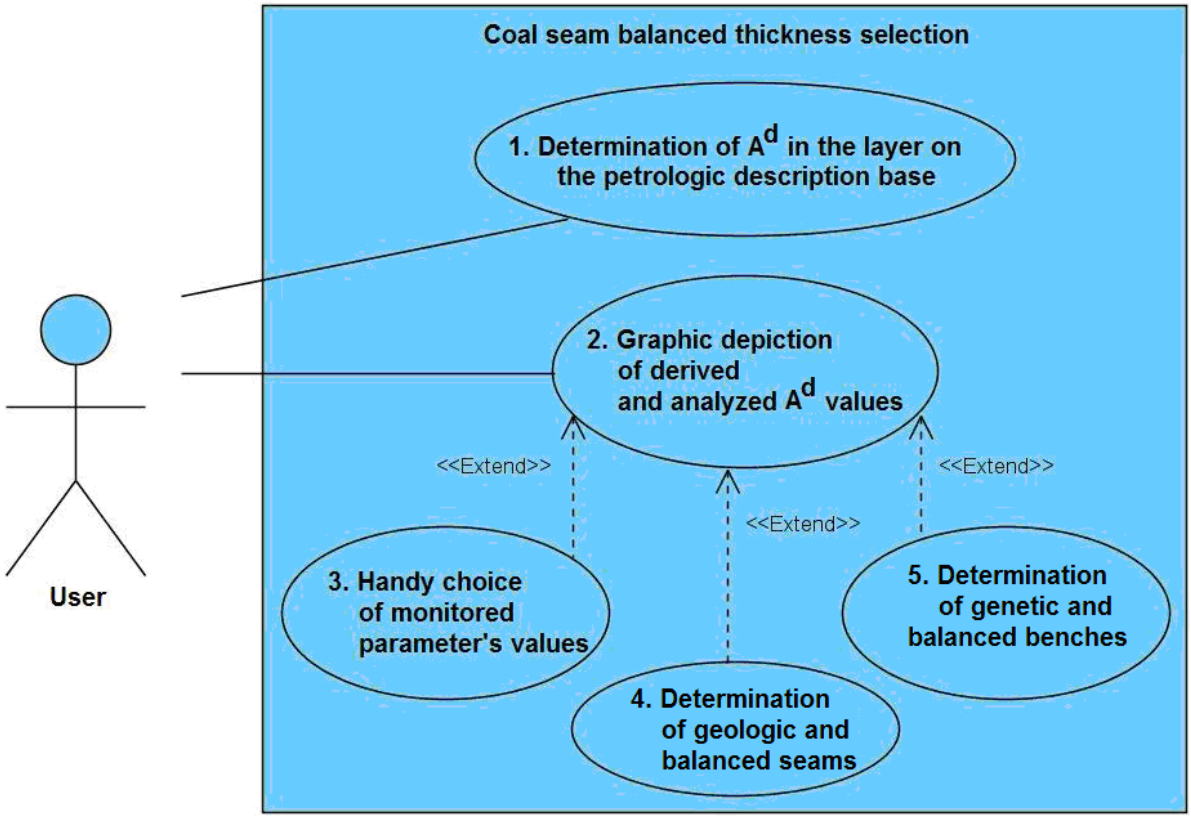


Fig. 1 Use case diagram

2 UTILIZATION OF APPLICATION

While determining economical thicknesses as a ground for formation of individual models of coal seams including coal benches and partings the most suitable is to determine the economical thickness according to one of the limit values A^d in seam profiles of all boreholes and then continue with a next value A^d again in all boreholes. From the point of view of data processing the system might be divided to several separate modules as follows:

- Module for deriving values of ash content A^d in layer based on petrographic description,
- Module for graphic depiction of borehole logs with values of ash content A^d,
- Module for selecting values of ash content A^d and other monitored parameters to each layer,
- Module for selecting geological and economical thicknesses of seam and computing weighted means of chosen parameters,
- Module for defining genetic benches and automated determining economical thicknesses of benches.

The first three modules are used as tools for gradual preparation of input data for the modules fourth and fifth - for selection of the economical bed in a seam and automatic generation of the economical thicknesses of benches. The first module has been involved in order to be able to determine the average values A^d in the seam at a later stage of solution even in such cases when the seam or some of its parts has not been analyzed. In such case it is necessary to specify the average values A^d at least based on the introduced approximate values acquired from the petrographic description. The third module allows selecting and assigning values of technological parameters to individual layers. The values of ash content are selected from both the values derived within the first module and the values acquired by techno-chemical analyses.

In subsequent chapters individual steps while working with the BilPol system are described and utilization of the software is explained.

2.1 Selection of input and output databases

The application uses two databases in the .MDB format involving together several tens of tables. It concerns the versatile deposit database [3] being used in many ways. From the viewpoint of creation of a geological deposit model 10 tables in total is used and processed containing data of planimetry of individual

boreholes, followed by data on petrographic coal composition, transition rocks and rocks in a chosen borehole or cutting. For some segments of the borehole logs the results of techno-chemical analyses of the monitored parameters are then recorded as follows:

A^d	Ash content on dry basis
V^{daf}	Content of volatile matter on dry ash-free basis
Q_s^{daf}	Gross calorific value on dry ash-free basis
S_t^d	Content of total sulphur on dry basis
As^d	Arsenic content on dry basis
Q_i^r	Net calorific value on as received basis

Further tables are then code lists containing petrographic classification of rocks or coefficient values used in calculations.

While selecting input data files through the buttons “Data file”, “Code file” and a target file through the button “Target file” that is used for storing the pre-processed data generated by the first module of the program (see below), a configuration file is then automatically generated by the program to an actual directory named config.ini. The file then includes the section input_output_files that defines paths to the last time selected databases. While starting the application next time there is then no need to specify the paths to the files repeatedly (see Fig. 2).

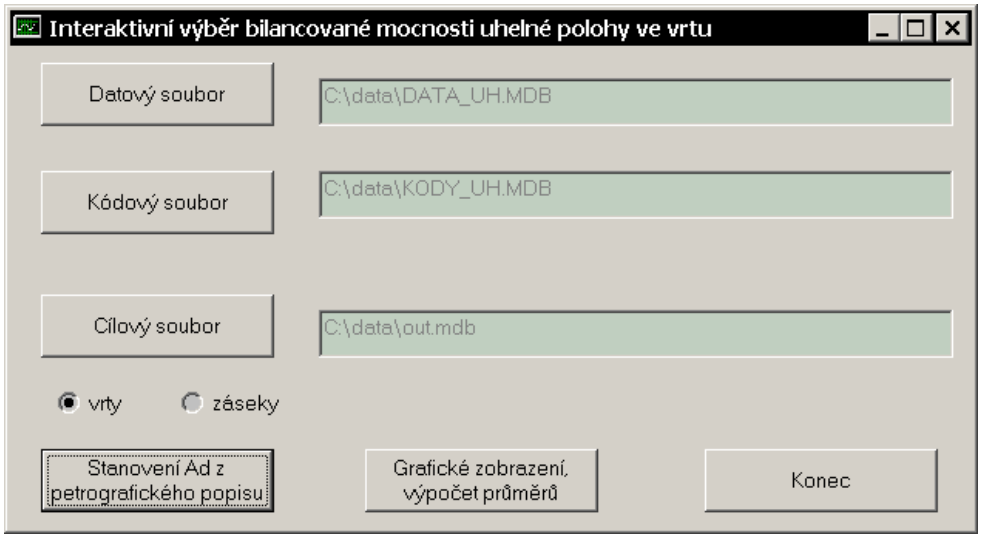


Fig. 2 Initial window dialog

If the user has formerly performed the derivation of an ash content A^d in a layer for objects of interest based on petrographic description (see below) he may approach from the initial window to displaying and calculating weighted means of ash content A^d. Otherwise it is necessary to determine the ash content A^d from petrographic description.

2.2 Module for deriving values of ash content A^d in a layer based on petrographic description

For modelling coal seams and determining average values of qualitative parameters it is necessary to know values of ash content A^d in all layers (segments) of coal seam profile. However, during geological survey the ash content has not been laboratory-determined in all layers. Especially in boreholes from the oldest period of survey samples for laboratory analyses were not usually taken from layers, so some coal beds and values of technological parameters are missing. Therefore in these seam parts an approximate ash content is determined that is specified from a petrographic description of the layer. Based on the petrographic description of the respective layer a calculation of ash content is performed according to agreed values of ash content A^d for individual types of rocks in all layers of the seam, where analytical quality data is missing. The agreed values result from the basic classification of coal and transient rocks according to A^d (e.g. for carbonaceous rocks with values ranging within 50 – 70 % A^d the average value is A^d = 60 %). As the rocks of the non-analyzed layers can contain interlayers of other rocks or coal, the assigned value A^d is adjusted by decrease of A^d (coal interlayers) or increase of A^d (rock interlayers).

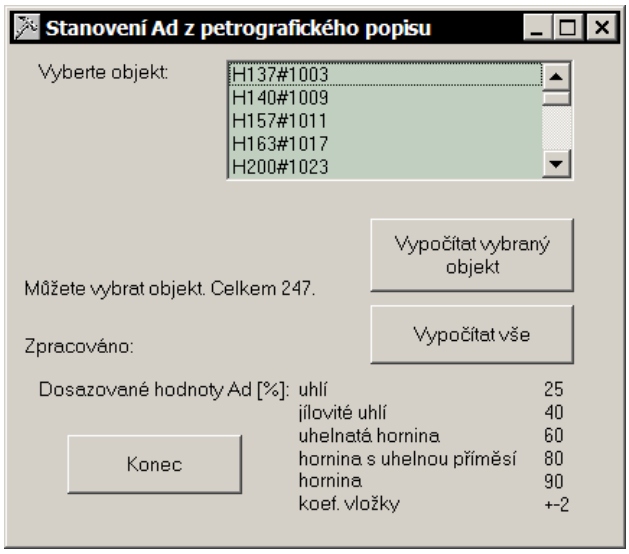


Fig. 3 Selection of object and calculation of ash content A^d based on petrographic description of rocks

This module is activated using the button "Determination of A^d from petrographic description". In the window of the first module (see Fig. 3) an object (thus borehole or cutting) may be selected and all its layers are automatically processed. It happens via the button "Calculate selected object". As well all objects may be selected for mass processing via the button "Calculate all".

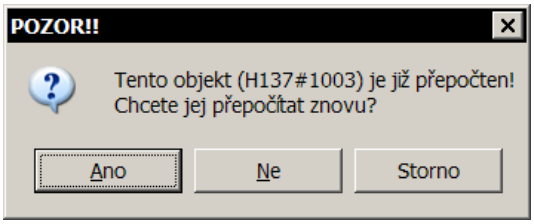


Fig. 4 Option to recalculate A^d values for actual object

Provided that the application finds some of the objects has already been processed the user will be notified of by a message and an offer whether he would like the values for the object to be recalculated or not (see Fig. 4).

In case of a positive answer he is enquired in addition, whether in a next occurrence of the previously processed object the values of this one and further ones are to be automatically recalculated without any next notification or not (see Fig. 5). Due to the automated procedure of defining the ash content A^d for individual layers the entire procedure is significantly accelerated and occurrences of possible errors caused by manual calculation are so eliminated.

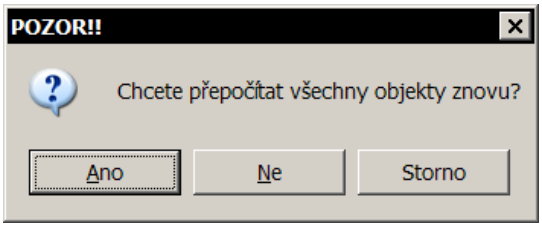


Fig. 5 Option to recalculate A^d values for all following objects

2.3 Module for graphic depiction of borehole logs with values of ash content A^d

Entry to the module is performed by the button "Graphic depiction, calculation of mean values". First a menu of objects is displayed from which it is possible to choose just one for displaying its log using either the button "Display" or double-click to the selected object. In the menu only such objects appear, for which the calculation of the ash content A^d has been performed based on a petrographic description of rocks (see Fig. 6). Visualization of logs of individual boreholes facilitates orientation during the further data processing of the coal database. These logs are depicted based on the values of the ash content A^d derived using the preceding

programming module and based on the values of techno-chemical analyses. The histogram leftmost illustrates the entire borehole log that is modelled from the derived values of the ash content A^d according to the petrographic description of rocks of the individual layers (see Fig. 7). Thicknesses of the individual layers are in the graphic depiction illustrated by height of the plotted segments, a quantity of the ash content A^d is then illustrated by their width. The single segments of the borehole log (left) are also completed with callouts of their depth location and the values of the percentage ash content A^d. The selected part of the borehole log may be for transparency (e.g. in "crowded" sites containing more layers of small thicknesses) zoomed in by selection of an interested interval (by selecting segments representing a top and base for the interval being zoomed), by specifying a zoom-in coefficient and using the button with the symbol "plus", respectively with the symbol "minus" to zoom out.

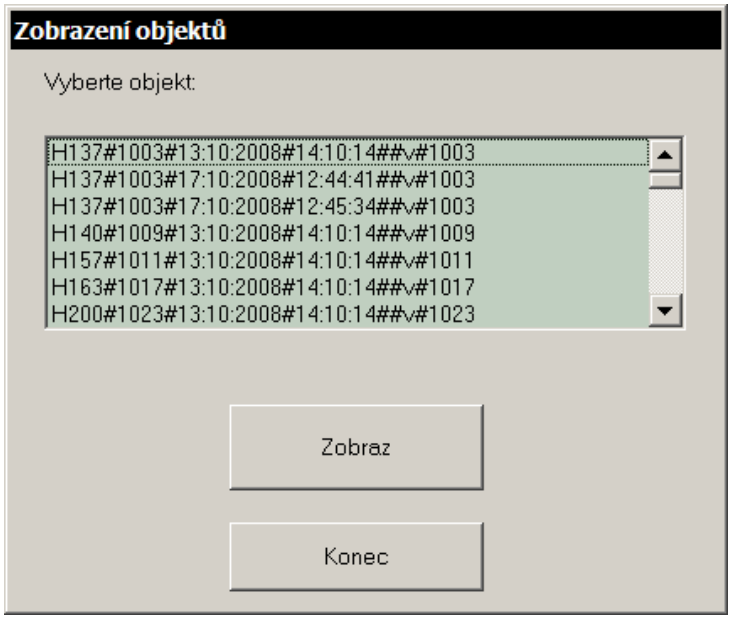


Fig. 6 Object selection dialog for graphic depiction of its log

Next to the histogram left other visualization elements may occur in the form of coloured vertical lines that give the user a clear overview of the stage of the model processing and processing results. The green vertical stripe informs about the interval which is in the input database indicated as an existing seam. After pointing the cursor a description appears containing the seam name, its depth location and the last recorded year the information refers to. Further the red vertical stripe indicates the part of the borehole log, for which the user has already made a selection of values of the ash content A^d and selection of other techno-chemical parameters (see below subsequent module) for each layer. To indicate the geological thicknesses of the seam the black stripe is used (see chapter "Module for selecting geological and economical thicknesses of seam"). This one delimitates the interval, for which the calculation of the weighted means of the monitored parameters has already been performed. The calculation results of the weighted mean of the ash content A^d and the depth location of the geological thicknesses of seam is displayed in the description after moving the mouse cursor. In the depth interval delimitated by the geological seam thickness economical segments are determined according to the limit value of the ash content A^d (see chapter "Module for selecting geological and economical thicknesses of seam"). Their occurrence is depicted by the light-green vertical stripe. For modelling a coal deposit divided by partings to genetic benches the application involves a special module that is used for determination of individual coal benches and partings.

Next to the leftmost plotted borehole log other histograms are displayed illustrating seam segments, for which the technological analyses have been performed. According to the way of sampling from the drill core the following types of samples or analyses are distinguished:

G – segment

SG – mixture from several layers which are not related by depth

PG – mixture of several (usually two) layers which are related by depth

S – mixture

DS – mixture with a partial loss of core

KG – data from well logging

For each type of analysis a histogram is plotted in a different colour. As the individual analyses need not to be carried out on the entire drill core, just the analyzed layers are displayed. As well some types of analyses need not to be carried out at all. At each layer callouts occur as well of the depth location of a segment and the value of the ash content A^d. Within one analysis type segments of overlaps may exist, thus such layers, for which the analysis of the given type has been carried out twice. Such layer is then hatched and in its callout it contains values of both analyses.

This method of graphic depiction of borehole logs with values of ash content A^d and indicated intervals which define geological and economical thicknesses of seams and benches with an option to use zoom in or zoom out facilitate considerably transparency and intelligibility of work with the application.

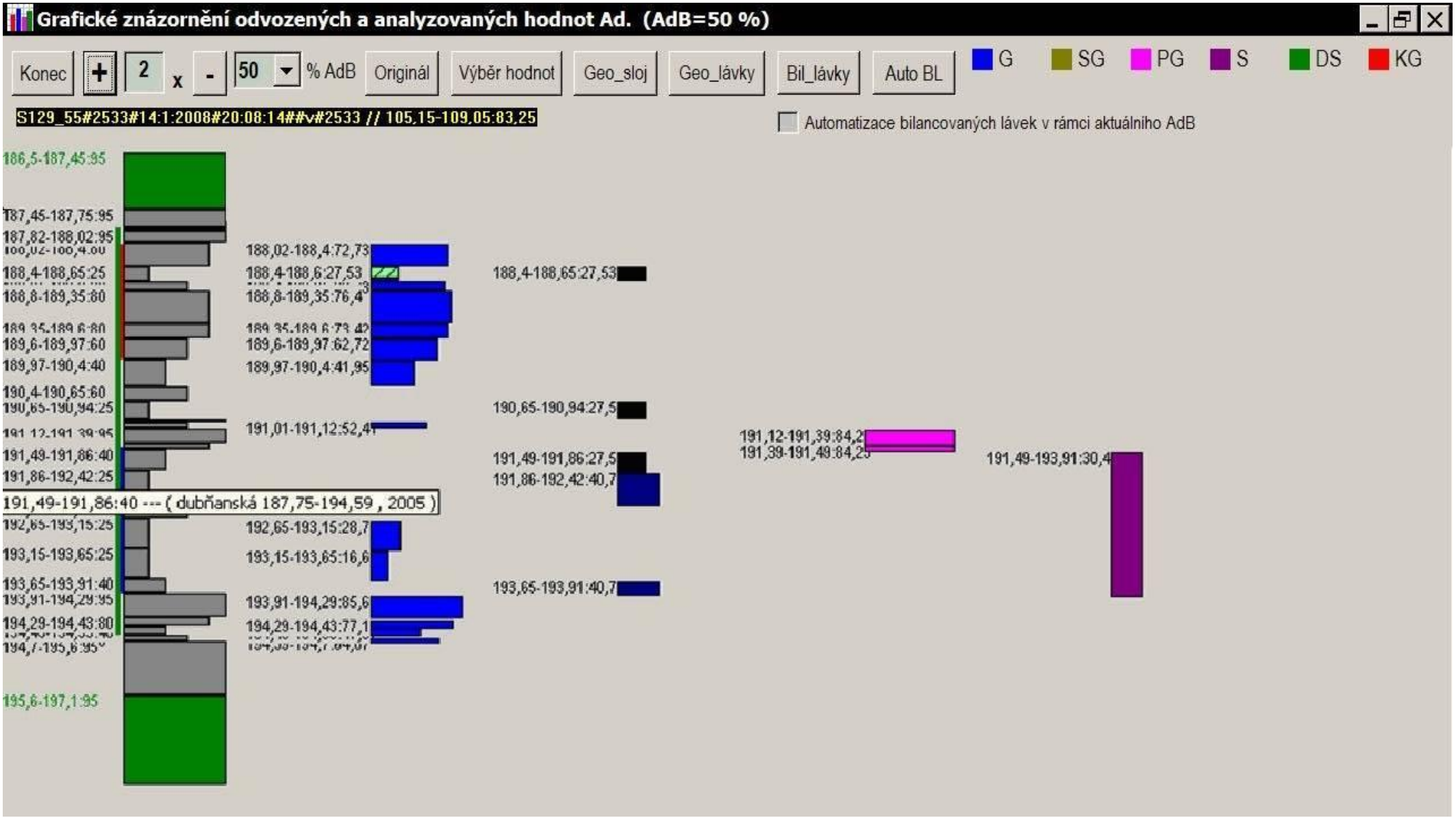


Fig. 7 Graphic depiction of borehole log with values A^d derived based on petrographic description and values acquired by techno-chemical analyses

2.4 Module for selecting values of ash content A^d and other monitored parameters to each layer

For data postprocessing it is necessary to determine in the "Module for graphic depiction of borehole logs" an interval of interest within the log of the actual borehole and to select on the interval for each layer the ash content A^d. The values of ash content are selected both from the values derived in the "Module for deriving values of ash content A^d in layer" based on the petrographic description and from results of techno-chemical analyses. After determining the top and base of the selected segment in the borehole log and by pressing the button "Select values" the user selects values A^d and other values of the monitored parameters displayed in the table (see Fig. 8). Provided that a selection of the values has already been performed for some layers, the depth intervals are written out in red colour and the user is informed on a possibility to overwrite the existing values. In the first step thus the values of the ash content A^d for each layer are selected namely either from the values of techno-chemical analyses ((G, SG, PG, ...), or from the values derived from the petrographic description. These values indeed need not to be selected on the entire interval within the selected segment in the borehole log, however the selection must be carried out on a continuous interval (see Fig. 9). This one is then highlighted by a yellow field. Within the continuous interval the selection of further monitored parameters (V^{daf}, Q_s^{daf}, S_t^d, As^d, Q_i^r) is then performed for each layer.

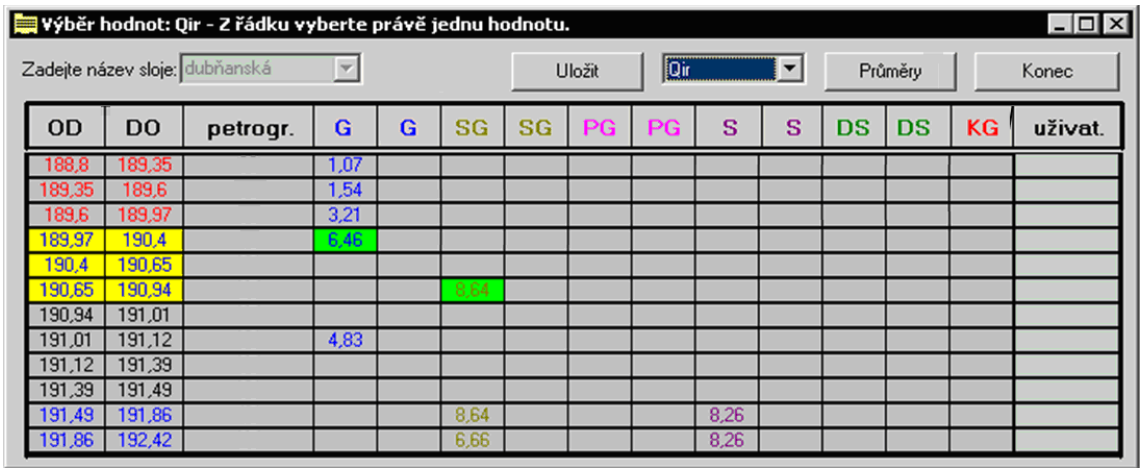


Fig. 8 Selection of values of ash content A^d and values of further monitored parameters (here Q_i^r) for individual layers

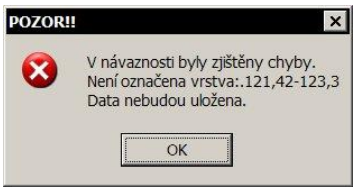


Fig. 9 Possible warning message when a discontinuous interval is selected

2.5 Module for selecting geological and economical thicknesses of seam and calculation of weighted means of chosen parameters

In the module the user may perform even a definition of a seam within a depth interval he determined in the preceding module by assignment of unique values of ash content A^d and values of other monitored parameters to each layer. By selecting a top and base of the seam (see Fig. 10) with a possibility to detail boundary values of the interval and assigning the seam name a geological thickness of the seam is defined, for which a weighted mean of the ash content A^d and weighted means of further monitored parameters are calculated

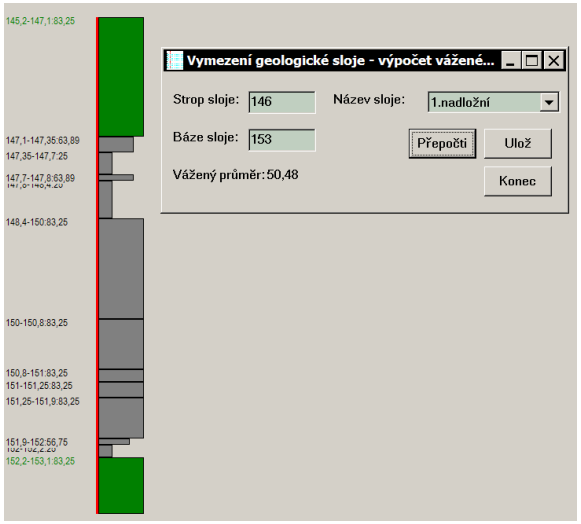
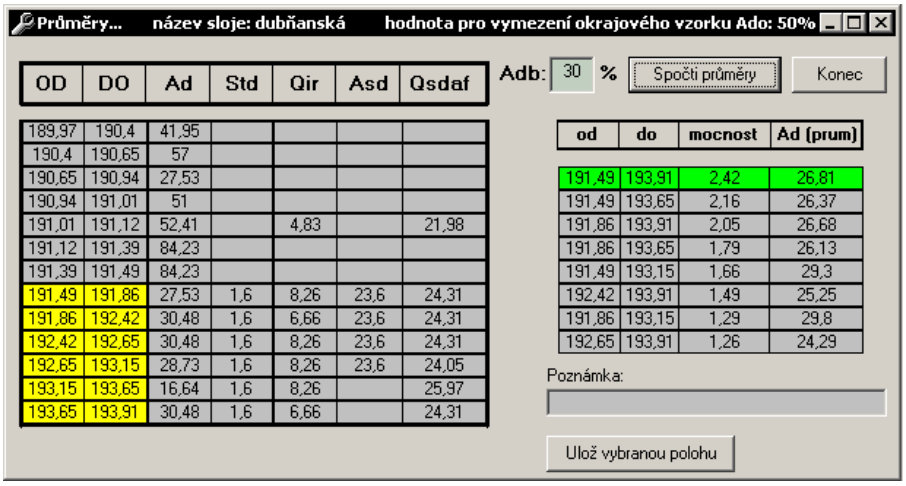


Fig. 10 Definition of base and top of geological seam

Within such determined geological thickness of seam the application then specifies the economical thicknesses of seam. It concerns continuous intervals, whose depth location within the borehole log does not exceed the interval of the geological thickness of seam. Within one geological thickness of seam the program automatically find the economical segments of the seam that meet the requirements of maximum value of weighted mean of ash content A^d. The limit values may be chosen arbitrarily, in the application the values 50, 40, 35 and 30 % of ash content A^d are specified for automatic determining economical segments (see Fig. 11).



OD	DO	Ad	Std	Qir	Asd	Qsdaf
189,97	190,4	41,95				
190,4	190,65	57				
190,65	190,94	27,53				
190,94	191,01	51				
191,01	191,12	52,41		4,83		21,98
191,12	191,39	84,23				
191,39	191,49	84,23				
191,49	191,86	27,53	1,6	8,26	23,6	24,31
191,86	192,42	30,48	1,6	6,66	23,6	24,31
192,42	192,65	30,48	1,6	8,26	23,6	24,31
192,65	193,15	28,73	1,6	8,26	23,6	24,05
193,15	193,65	16,64	1,6	8,26		25,97
193,65	193,91	30,48	1,6	6,66		24,31

od	do	mocnost	Ad (prum)
191,49	193,91	2,42	26,81
191,49	193,65	2,16	26,37
191,86	193,91	2,05	26,68
191,86	193,65	1,79	26,13
191,49	193,15	1,66	29,3
192,42	193,91	1,49	25,25
191,86	193,15	1,29	29,8
192,65	193,91	1,26	24,29

Fig. 11 Selection from automatically found economical seam parts

2.6 Module for defining genetic benches and automated determining economical thicknesses of benches

The module allows within geological thicknesses of seam of individual boreholes defining genetic coal benches separated by partings. The application in the coal benches calculates the weighted means of ash content A^d and further technological parameters and simultaneously specifies automatically thicknesses of partings among the benches. In the South-Moravian lignite coalfield the seam is divided at the most to 4 coal benches indicated bottom-up L1, L3, L5 and L7 that are separated by partings P2, P4 and P6 (see Fig. 12).

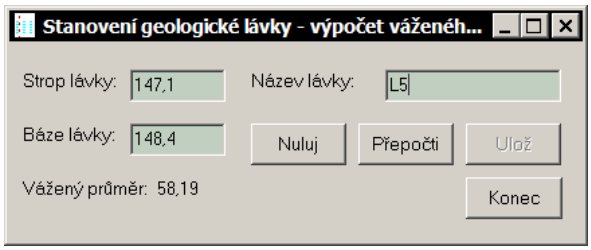


Fig. 12 Defining geological bench L5

On some sites of a coal basin the seams do not need to contain the above mentioned number of benches, as these could join in one bench or nip out. For these cases zero thicknesses of benches may be defined in this application by the button "Reset".

The application for all genetic benches generates automatically economical thicknesses of benches that gradually meet criteria for maximum average value of ash content A^d (50 %, 40 %, 35 %, 30 % of ash content). Within the automatic generation of thicknesses of economical benches for an actual genetic bench (e.g. the bench L5) several results of economical benches are generated that meets the just determined criterion for the maximum average ash content A^d (e.g. 50 %). The results of the found economical bench thicknesses are arranged in descending order according to their thicknesses (see Fig. 13). The user then selects the individual results of the economical benches and their depth integration within the genetic bench is displayed. Finding the economical thicknesses of benches may be furthermore automated in next two steps. In the first step of automation the economical thicknesses for a currently processed bench (e.g. L5) and a currently selected limit value of ash content A^d (e.g. 50 %) may be found. The second step of automation ensures processing of all benches (L1, L3, L5, L7) and thus automated finding of the economical thicknesses within the entire processed borehole log, of course with the actually selected limit value of ash content A^d (e.g. 50 %). The third and last step of automation ensures the full automation of finding of the economical thicknesses of benches, thus it solves the transit through all existing benches in the given borehole log and searches the thicknesses gradually meeting criteria of the limit value of ash content A^d (e.g. 50 %, 40 %, 35 %, 30 %). The result is finally the model of genetic benches and the variant models of economical benches for individual maximum average ash contents A^d.

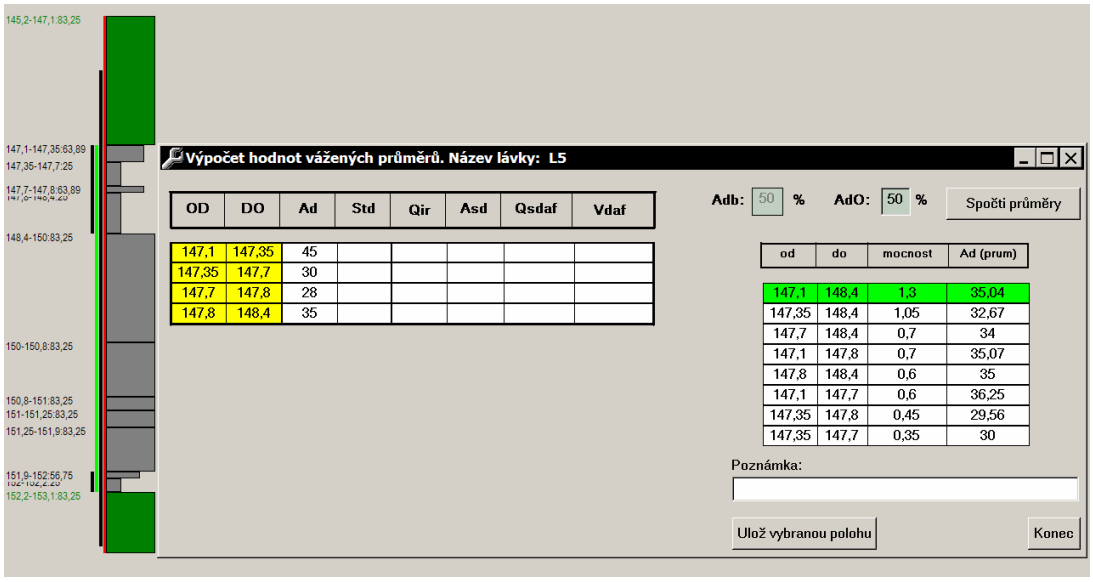


Fig. 13 Selection from automatically found economical benches

3 CONCLUSIONS

The above described software system brings through visualization of processed data its transparency and considerable acceleration of work while determining both geological thicknesses of seam in boreholes and economical segments inside these geological thicknesses and while computing weighted means of ash content A^d and further values of technological parameters.

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[5] STANĚK et al.: *Interaktivní programový systém pro aplikaci moderních metod hodnocení uhelných ložisek a jejich dílčích částí v komplikovaných podmínkách*. In Sb. vědeckých prací VŠB – TU Ostrava, monografie 16, rok 2006, roč. LII, řada hornicko – geologická. 167 pp. ISBN 80-248-0956-7.

RESUMÉ

The modelling of coal seam and subsequent calculation of resources that are a subject of the interactive programming system of rating of coal deposits [5] based on data stored in a database results from information on seam expressed by a economical thickness and corresponding to average values of monitored deposit attributes on site of affecting seam by a survey work. The determination of the presented derived input data is affected by a series of factors, which are non-uniform methods of sampling for techno-chemical analyses, complicated construction of seam or criteria for determination of economical seam parts.

To facilitate the rating of coal seams the BilPol application has been developed, which is used for determination of geological and economical thicknesses of seams and their genetic benches affected in individual boreholes during a deposit survey. Through the use of the application not only thicknesses of seam and benches are easy to be determined, but also average values of principal technological parameters (except for ash content A^d also V^{daf}, Q_s^{daf}, S_t^d, As^d, Q_i^r). The application in a transparent form of borehole log displays data from database of petrographic descriptions of captured rocks and results of techno-chemical analyses; completes missing data if possible based on agreed rules; provides optimum solution of selecting economical thickness according to actual values of limit parameters for selection of economical thickness and determines average values of technological parameters in a user-confirmed economical thickness. Results are stored to the database in the format, which applications for computing resources work over, from the interactive system of rating of coal deposits. It is possible to change values of limit parameters for selecting of economical thickness through the use of the application to prepare input data for a variant solution of a coal seam model. In conformity with the conception of the developed system the application is usable for all types of coal deposits in the Czech Republic.